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ABSTRACT

This student workbook contains units five and six of a six-unit physical science course. The program is intended for high school students who have not had a chemistry or physics course, and is designed to be self instructional. Unit five involves experiments and problems in these subject areas: temperature versus heat; units of heat; specific heat; law of heat exchange; and thermal expansion of solids, liquids, and gases. Unit six includes activities related to heat of fusion of water, vaporization and condensation, heat of vaporization; and methods of heat transfer. Data tables for experiments and space to work problems are provided in the workbook. Simple algebra is used in working the problems. This work was prepared under an ESEA Title III contract. (PR)

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PHYSICAL SCIENCE

UNITS V & VI

FIELD TEST COPY

This workbook is part of the instructional system in Physical Science developed at Washington State University, Department of Education, for the HIGH SCHOOL FOR ONE project.

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NAME ______________

PHYSICAL SCIENCE
UNITS V & VI

UNIT	CARTRIDGE	DATE COMPLETED
V	1	
V	2	
V	3	
V	4	
V	5	
V	6	
V	7	
V	8	
V	9	
V	10	
V	11	
UNIT V - POST TEST		
VI	1	
VI	2	
VI	3	
VI	4	
VI	5	
VI	6	
VI	7	
VI	8	
VI	9	
VI	10	
VI	11	
UNIT VI - POST TEST		

Laboratory Notebook #5

B A S I C P H Y S I C A L S C I E N C E

UNIT V

SECTION I: TEMPERATURE VERSUS HEAT

Section IA: Deriving a definition of temperature

Temperature of the water in Beaker No. 2 before hot water is added:

_____________ °C

Temperature of the water in Beaker No. 2 after hot water has been added and stirred for two minutes:

_____________ °C

Explanation as to why the temperature of the colder water in Beaker No. 2 increased when hot water was added to it.

State the definition of temperature below.

Section IB: Thermal energy

Temperature of the water in Beaker No. 1:

_____________ °C

Temperature of the water in Beaker No. 2:

_____________ °C

The time it takes the water in Beaker No. 2 to reach room temperature:

_____________ minutes

The temperature of the water in Beaker No. 1 when the water temperature of Beaker No. 2 is at room temperature:

______________ °C

State the definition of thermal energy in the space below.

State the definition of heat in the space below.

Record the differences between the concepts of heat and temperature in the space below.

Section IC: Questions relating to temperature and heat (thermal energy)

Answer these questions relating to temperature and heat (thermal energy). Check your answers before continuing.

1. Draw a line under the item that contains the greater amount of heat (thermal energy).

   a. a soldering iron or a needle, both at 150°C

   b. a teakettle full of boiling water or a cup of boiling water

   c. 20 kg of ice at -10°C or 10 kg of ice at -10°C

   d. a milliliter of liquid air or a liter of liquid air both at -189°C

   e. ten grams of water at 50°C or 100 grams of water at 40°C

2. If you had a kilogram lead block and a 500 gram lead block, both measured the same temperature, explain why they wouldn't contain the same amount of heat (thermal energy). Use the terms, temperature, kinetic energy, and heat (thermal energy) in your answer.

SECTION II: UNITS OF HEAT

Section IIA: Definitions of heat--British Thermal Unit

Place the two values that determine the amount of heat contained in a body in the space below.

1.

2.

Write the definition of the English unit of heat, the British Thermal Unit, in the space below.

Write the formula used to compute the amount of heat (measured in BTU's) needed to change the temperature of a given amount of water in the space below.

Problems

Problem 1 - How much heat is needed to raise the temperature of 15 pounds of water from 80°F to 200°F? Work this problem as it is worked on the tape and slides.

Problem 2 - How much heat is lost if 5 pounds of water are cooled from 100°F to 20°F? Work this problem as it is worked on the tape and slides.

Problem 3 - How much heat is needed to raise the temperature of 80 pounds of water from 100°F to 212°F? Check your answer to this problem before going on to the next problem.

Problem 4 - How much heat is lost if 50 pounds of water, at a temperature of 212°F, are cooled to a temperature of 100°F? Check your answer to this problem before continuing.

Section IIB: Calorie--cgs system

Place the definition of a calorie (cal.) in the space below.

Write the formula used to compute the amount of heat (measured in calories) needed to change the temperature of a given mass of water in the space below.

Problems

Problem 1 - How much heat is needed to raise the temperature of 250 grams of water from 20°C to 80°C? Solve this problem as it is solved on the tape and slides.

Problem 2 - How many calories of heat are gained by 600 grams of water when its temperature changes from 20°C to 100°C? Check your answer before continuing.

Problem 3 - Compute the final temperature of 500 grams of water, initially at 20°C, if 20,000 calories of heat are added to it. Solve this problem as it is solved on the tape and slides.

Problem 4 - Compute the final temperature of 200 grams of water, initially at 30°C, if 8,000 calories of heat are added.

Section IIC: Calorie and BTU conversions

Place the relationships and conversions of the calorie and BTU in the space below.

1 BTU = __________ calories.

To change BTU's into calories ______________ by 252.

To change calories into BTU's ______________ by 252.

Problems

Problem 1 - How many calories are equivalent to 30 BTU's?

Problem 2 - How many BTU's are equivalent to 6,300 calories?

Section IID: Data for the determination of the quantity of heat needed to warm a specific mass of water

mass of water ____________ grams

initial temperature of water ________°C

final temperature of water _______°C

Calculate the amount of heat, in calories, needed to raise the initial temperature to the final temperature.

Section IID: (Cont'd)

amount of heat absorbed by the water ___________ calories

Convert the calculated number of calories to BTU's in the space below.

amount of heat absorbed by the water ___________ BTU's

Section IIE: Questions relating to heat units

In the following statements, place the correct word or term that best completes them in the blank.

1. The amount of heat required to raise the temperature of one gram of water from 14.5°C to 15.5°C is called a ___________.
2. The amount of heat required to raise the temperature of one pound of water from 10°F to 11°F is called a ___________.
3. A calorie is (larger, smaller) ___________ than a BTU.
4. To change calories to BTU's, you must ___________.
5. The English unit of heat is called a ___________.
6. The cgs unit of heat is called a ___________.
7. When calculating a quantity of heat measured in BTU's, the mass of the water is measured in ___________ and the temperature change is measured in ___________ degrees.
8. When calculating a quantity of heat measured in calories, the mass of the water is measured in ___________ and the temperature change is measured in ___________ degrees.
9. If heat is added to water, the temperature of the water ___________.
10. One BTU is equal to ___________ calories.

Check your answers to the fill-in questions before answering the following problems.

Problems

Problem 1 - One kilogram (1000 grams) of water is heated from 15°C to 75°C. How many calories of heat were used to make this temperature change? Check your answer before working the next problem.

Problem 2 - How much heat is lost if 20 pounds of water are cooled from 180°F to 100°F? Give your answer in BTU's and calories. Check your answers before working the next problem.

Problem 3 - Compute the final temperature of a kilogram of water, initially at 20°C, if 40,000 calories of heat are added. Check your answer before working the next problem.

Problem 4 - A burner used to heat 10 pounds of water raised its temperature from 30°F to 100°F. How much heat did the burner supply to the water? Check your answer before continuing.

SECTION III: SPECIFIC HEAT

Section IIIA: Data table for determining the specific heats of paraffin oil and water

Record the initial temperature of each liquid and the temperature every minute, for five minutes, after you start to heat the liquid.

SUBSTANCE	Initial Temp.	Temp. After 1 Minute of Heating	Temp. After 2 Minutes of Heating	Temp. After 3 Minutes of Heating	Temp. After 4 Minutes of Heating	Temp. After 5 Minutes of Heating
Water Beaker A	°C	°C	°C	°C	°C	°C
Paraffin Oil Beaker B	°C	°C	°C	°C	°C	°C

Section IIIB: Defining specific heat

State the three values that are important when heat units are defined.

1.

2.

3.

State the definition of specific heat in the space below.

Place the units for expressing specific heat in the space below.

1.

2.

Write the heat equation in the space below.

Section IIIC: Problems

Problem 1 - Compute the heat needed to raise the temperature of 15 grams of aluminum, of specific heat 0.22 cal/C°, from 100°C to 250°C.

Problem 2 - How many calories of heat are needed to raise the temperature of 80 grams of iron from 0°C to 300°C? The specific heat of iron is 0.11 cal/g/C°. Check your answer to this problem before working the next problem.

Problem 3 - How many BTU's are needed to raise the temperature of 5 pounds of mercury from 20°F to 100°F? The specific heat of mercury is 0.033 BTU/lb/F°. Check your answer before continuing.

SECTION IV: LAW OF HEAT EXCHANGE

Section IVA: Data table for the law of heat exchange experiment

	Trial I	Trial II
1. Weight of smaller can of the calorimeter	g	g
2. Weight of cold water	g	g
3. Initial temperature of the cold water	°C	°C
4. Initial temperature of the calorimeter	°C	°C
5. Initial temperature of the warm water	°C	°C
6. Final temperature of the mixture and calorimeter	°C	°C
7. Weight of the mixture of water and the calorimeter	g	g
8. Weight of the warm water	g	g
9. The specific heat of the calorimeter	0.22 cal/g/C°	0.22 cal/g/C°
10. Heat gained by the calorimeter	cal	cal
11. Heat gained by the cold water	cal	cal
12. Heat lost by the warm water	cal	cal

Section IVB: Calculations for the law of heat exchange experiment

Calculate the heat gained by the aluminum calorimeter in the space below. The specific heat of aluminum is 0.22 cal/g/C°. Record your answer in the data table on page 11.

Calculate the heat gained by the cold water that was initially placed in the calorimeter. Remember that the specific heat of water is 1 cal/g/C°. Record your answer in the data table on page 11.

Calculate the heat lost by the warm water. Record your answer in the data table on page 11.

Section IVC: Law of conservation of heat

Compare the amount of heat lost by the warm water to the amount of heat gained by the cold water and calorimeter. Where is heat lost that was not considered in the calculations?

Write the law of conservation of heat in the space below.

Section IVD: Questions relating to heat exchange

In the following statements, place the correct word or term that best completes them in the blank.

1. The amount of heat required to raise the temperature of one gram of a substance one degree centigrade is called the ___________ of the substance.

2. The amount of heat required to raise the temperature of one pound of a substance one degree Fahrenheit is called the ___________ of the substance.

3. The units that specific heat is measured in are ___________ or ___________.

4. The specific heat of water is ___________.

5. Most other substances have a (higher, lower) ___________ specific heat than that of water.

6. When two substances at different temperatures are mixed and the mixture comes to a final temperature, the heat ___________ equals the heat ___________.

7. As a substance is heating, heat is (absorbed, lost) ___________.

8. As a substance is cooling, heat is (absorbed, lost) ___________.

9. The formula for determining the amount of heat lost or gained by a substance when it cools or warms is ___________.

10. The sum of the heat given off by hot objects equals the sum of the heat received by cold objects. This statement is known as the law of ___________.

Check your answers to the fill-in questions before working the problems.

Problems

Problem I - When 100 g of hot water at 90°C is mixed thoroughly with 200 g of cold water at 0°C, the temperature of the mixture is 30°C. Show that the heat lost by the hot water is exactly equal to that gained by the cold water. Check your answer before working the next problem.

Problem 2 - The specific heat of copper is 0.09 cal/g/C°. How much heat does it take to raise the temperature of 200 g of copper from 40°C to 100°C? Check your answer before continuing.

Problem 3 - In an experiment similar to the one you did in the laboratory, a calorimeter was filled with 150 grams of cold water. The mass of the calorimeter was 60 grams. The specific heat of the calorimeter is 0.10 cal/g/C°. The temperature of the cold water and calorimeter initially was 20°C. 100 grams of hot water, at a temperature of 80°C, was added. After stirring, the final temperature of the mixture and calorimeter was 43.4°C. Show that the heat gained by the calorimeter and cold water was, within experimental error, very nearly equal to the heat lost by the hot water. Check your answer to this problem before continuing.

SECTION V: SPECIFIC HEAT OF A METAL

Section VA: Data table for the determination of the specific heat of aluminum and lead

	Aluminum	Lead
1. Mass of the metal	g	g
2. Mass of the calorimeter	g	g
3. Mass of the calorimeter and water	g	g
4. Mass of the water (3 - 2)	g	g
5. Specific heat of the calorimeter	0.22 cal/g/C°	0.22 cal/g/C°
6. Initial temperature of solid (temperature of boiling water)	°C	°C
7. Initial temperature of water and calorimeter	°C	°C
8. Final temperature of solid, water and calorimeter	°C	°C
9. Temperature change of the solid (6 - 8)	°C	°C
10. Temperature change of the water and calorimeter (8 - 7)	°C	°C
11. Calories gained by the water (4 x 1 cal/g/C° x 10)	cal	cal
12. Calories gained by the calorimeter (2 x 0.22 cal/g/C° x 10)	cal	cal
13. Total calories gained by the water and calorimeter (11 + 12)	cal	cal
14. Calories lost by the solid (1 x 5 x 9)	cal	cal
15. Calculate the specific heat of the solid (set 14 equal to 13 and solve for S)	cal/g/C°	cal/g/C°
16. Accepted value for the specific heat of the solid	0.22 cal/g/C°	0.031 cal/g/C°
17. Error (difference between 15 & 16)		
18. Percentage error (divide 17 by 16 and multiply by 100)	%	%

Section VB: Calculations for the specific heat of aluminum

Calculate the temperature change of the aluminum solid in the space below. Record this answer in your data table on page 15.

Calculate the temperature change of the water and calorimeter in the space below. Record this answer in your data table on page 15.

Calculate the calories gained by the water in the space below. Record this answer in your data table on page 15.

Calculate the calories gained by the calorimeter in the space below. Record this answer in your data table on page 15.

Calculate the total heat gained by the water and calorimeter in the space below. Record this answer in your data table on page 15.

Calculate the heat lost by the aluminum solid in the space below. Record this answer in your data table on page 15.

Calculate the specific heat of the aluminum solid in the space below. Record this answer in your data table on page 15.

Calculate the error in your experiment in the space below. Record this answer in the data table on page 15.

Calculate the percentage error in the experiment in the space below. Record this answer in the data table on page 15.

Section VC: Procedure for determining the specific heat of lead

1. Fill the steam generator about one-half full of water and start the water boiling.

2. Weigh the lead cylinder on your triple-beam balance. Weigh it to the nearest tenth of a gram.

3. Tie a string, about 30 cm long, to the hook of the lead cylinder. When the water starts to boil, lower the cylinder into the boiling water.

4. Weigh the smaller can of the calorimeter on your triple-beam balance. Weigh it to the nearest tenth of a gram.

5. Fill the smaller can of the calorimeter three-fourths full of water. Weigh the calorimeter and water on the triple-beam balance. Weigh it to the nearest tenth of a gram.

6. Place the smaller can of the calorimeter inside the larger can of the calorimeter. Take the temperature of the cold water to the nearest two-tenths of a degree centigrade. This is also the temperature of the calorimeter.

7. Measure the temperature of the boiling water. This is the temperature of the solid. Record this temperature to the nearest two-tenths of a degree centigrade.

8. Lift the solid by means of the string, and hold it in the steam just above the water long enough to let the water which adheres to the solid evaporate. Then quickly place the solid into the calorimeter of cold water. Be careful not to spill any water. Stir the water with the thermometer and read the highest temperature of the water to the nearest two-tenths of a degree centigrade.

9. Do all the calculations asked for on the data table. These calculations are to be done in the spaces provided in your notebook. Place these answers in the data table on page 15.

Section VD: Calculations for the specific heat of lead

Calculate the temperature change of the lead solid in the space below. Record your answer in the data table on page 15.

Calculate the temperature change of the water and calorimeter in the space below. Record your answer in the data table on page 15.

Calculate the calories gained by the water in the space below. Record your answer in the data table on page 15.

Calculate the calories gained by the calorimeter in the space below. Record your answer in the data table on page 15.

Calculate the total heat gained by the water and calorimeter in the space below. Record your answer in the data table on page 15.

Calculate the heat lost by the lead in the space below. Record your answer in the data table on page 15.

Calculate the specific heat of the lead solid in the space below. Record your answer in the data table on page 15.

Calculate the error in your experiment in the space below. Record your answer in the data table on page 15.

Calculate the percentage error in your experiment in the space below. Record your answer in the data table on page 15.

SECTION VI: EXPANSION

Section VIA: Expansion of solids

Why do solids expand when they are heated? Place your answer in the space below. Check your answer before continuing.

Section VIB: Ball and ring expansion experiment

1. What happened when the ball was heated for 30 seconds in the laboratory burner flame and then passed through the ring?

2. What happened when the ball was heated strongly for two minutes in the flame? Did the ball pass through the ring?

3. What happened when the hot ball was cooled and then you tried to pass it through the ring?

Explain the above observations in the space below. Check your answer before continuing.

Section VIC: Compound bar experiment

What happened when the compound bar was heated in the flame (with the brass side next to the flame)? Record your observations in the space below.

What happened when the hot compound bar was plunged into a 250 ml beaker of cold water? Record your observations in the space below.

Explain why the compound bar bends with the brass strip on the outside of the curve when it is heated, and with the steel strip on the outside of the curve when it is cooled.

SECTION VII: LINEAR EXPANSION OF SOLIDS

Section VIIA: Definition of the coefficient of linear expansion

Write the definition for the coefficient of linear expansion in the space below.

Section VIIB: Data table for the coefficient of linear expansion of a metal

	Aluminum	Brass
1. Length of the rod	mm	mm
2. Length of the long lever arm	mm	mm
3. Length of the short lever arm	mm	mm
4. Ratio of the lever arms (2 ÷ 3)		
5. Initial temperature	°C	°C
6. Final temperature	°C	°C
7. Change in temperature (6 - 5)	°C	°C
8. Initial scale reading (should be zero)	mm	mm
9. Final scale reading	mm	mm
10. Difference in scale readings (9 - 8)	mm	mm
11. Actual expansion of rod (10 ÷ 4)	mm	mm
12. Expansion of the rod per degree (11 ÷ 7)	mm	mm
13. Expansion of the rod per millimeter per degree (12 ÷ 1) (coefficient of linear expansion)	mm	mm
14. Accepted value of coefficient of linear expansion	2.3×10^{-5}/C°	1.9×10^{-5}/C°
15. Error (difference between 14 & 13)	/C°	/C°
16. Percentage error (error divided by accepted value times 100)	%	%

Section VIIC: Calculations for determining the coefficient of expansion of the aluminum rod

Calculate the ratio of the lever arms in the space below. Record your answer in the data table on page 22.

Calculate the temperature change of the aluminum rod in the space below. Record your answer in the data table on page 22.

Calculate the difference in the scale readings in the space below. Record your answer in the data table on page 22.

Calculate the actual expansion of the aluminum rod in the space below. Record your answer in the data table on page 22.

Calculate the expansion of the aluminum rod, per degree, in the space below. Record your answer in the data table on page 22.

Calculate the error in your experiment in the space below. Record your answer in the data table on page 22.

Calculate the percentage error in the space below. Record your answer in the data table on page 22.

Section VIID: Procedure for determining the coefficient of expansion of the brass rod

1. Set the steam generator on the tripod. Fill it two-thirds full of water and start the water boiling.

2. Measure the length of the brass rod to the nearest millimeter. Record this measurement in the data table.

3. Remove the steam jacket of the expansion apparatus. Place the brass rod in the jacket and replace the jacket in the metal frame.

4. Adjust the thumbscrew at the fixed end of the rod. The screw is on the left end of the rod so that the tip of the long arm of the lever will coincide with the zero mark on the scale. This reading should be zero. Record this reading.

5. Place the thermometer in the proper position of the steam jacket and take the temperature reading to the nearest .2°C. Record this under the initial temperature for the brass rod. This temperature should be very close to room temperature.

6. Connect the steam generator to the steam jacket of the apparatus by means of the rubber tubing. The rubber tubing is connected to the fitting on the left of the generator. Place the top on the steam generator and pass steam into the jacket of the apparatus. Continue to pass steam into the steam jacket until the thermometer has risen to its highest reading and remained there for three minutes.

7. Record the temperature, to the nearest .2°C, under the final temperature. Record the scale reading to the nearest millimeter.

8. Turn off the burner, and disconnect the rubber tubing. Remove the thermometer.

9. Do the following calculations for the experiment. Record your answers in the data table on page 22.

Section VIIE: Calculations for determining the coefficient of expansion of the brass rod

Calculate the temperature change of the brass rod in the space below. Record your answer in the data table on page 22.

Calculate the difference in the scale readings in the space below. Record your answer in the data table on page 22.

Calculate the actual expansion of the brass rod in the space below. Record your answer in the data table on page 22.

Calculate the expansion of the brass rod,per degree,in the space below. Record your answer in the data table on page 22.

Calculate the expansion of the brass rod per millimeter per degree in the space below. Record your answer in the data table on page 22.

Calculate the error in this experiment in the space below. Record your answer in the data table on page 22.

Calculate the percentage error in this experiment in the space below. Record your answer in the data table on page 22.

Section VIIF: Questions on the expansion of solids

1. When a metal rod is heated, does it expand in length only? Explain.

2. Form three possible sources of error in this experiment. Check your answers to questions one and two before continuing.

   1.

   2.

   3.

Place the formula for determining the change of length of a solid in the space below.

Section VIIG: Problems on the expansion of solids

Sample problem: An iron rod is 60 cm long at 0°C. How much will it expand when heated to 80°C? The coefficient of linear expansion of iron is 1.1×10^{-5}/C°. Work this problem along with the tape and slides.

Problem 1 - Compute the increase in length of a 10-foot steel rod if it is heated from 20°C to 520°C. The coefficient of linear expansion of steel is 1.0×10^{-5}/C°. Check your answer to this problem before working the next problem.

Problem 2 - Compute the increase in length of a glass rod, 100 cm long, when heated from 20°C to 400°C. The coefficient of linear expansion of glass is 9.0×10^{-6}/C°. Check your answer to this problem before working the next problem.

Problem 3 - Compute the expansion of the Golden Gate steel bridge (4200 feet long) from a winter temperature of 10°C to a summer temperature of 80°C. The coefficient of linear expansion of steel is $1.0 \times 10^{-5}/C°$. Check your answer to this problem before continuing.

Section VIIH: Coefficient of volume expansion

Place the definition of the coefficient of volume expansion in the space below.

SECTION VIII: EXPANSION OF LIQUIDS

Section VIIIA: Data table for the expansion of liquids

Temperature °C	Rise of Liquid in Tube (cm)		
	Water	Burner Fuel	Glycerine
Initial Temp. of Water	0.0	0.0	0.0
Initial Temp. + 10°C			
Initial Temp. + 20°C			
Initial Temp. + 30°C			
Initial Temp. + 40°C			
Initial Temp. + 50°C			

Section VIIIB: Questions on the expansion of liquids

1. Which liquid expanded the most? Which liquid expanded the least?

2. How many more times greater is the expansion of burner fuel than that of glycerine or water over the temperature range of 30°C to 50°C?

3. Why did each liquid rise in the tube when it was heated?

SECTION IX: EXPANSION OF GASES

Answer these questions relating to expansion of gases. Check your answers.

1. The attractive forces between the atoms that make up a solid are (stronger, weaker) ______________ than the attractive forces of liquids or gas molecules.

2. The rate of thermal expansion of gases is (larger, smaller) ______________ than the thermal expansion rates of liquids or solids.

3. Different gases have (the same, different) _____________ rates of thermal expansion.

4. Different solids have (the same, different) ____________ rates of thermal expansion.

5. Different liquids have (the same, different) ___________ rates of thermal expansion.

6. Gas molecules are (farther apart, closer together) ______________ than the molecules that make up a liquid.

7. Gases (expand, contract) ___________ upon heating and (expand, contract) _________ upon cooling.

8. In order for the gas molecules to expand in the test tube, they must exert a ____________ on the bottom of the wooden piston when they are heated.

9. Gas molecules (do, do not) _______ respond to the slightest temperature change.

10. Gas molecules move (faster, slower) __________ than liquid molecules at any one particular temperature.

This is the end of Unit V. Review your notes and then ask your instructor for the examination covering this unit.

Laboratory Notebook #6

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UNIT VI

SECTION I: DEFINITION OF TERMS

Section IA: Defining temperature and heat

Write the definition of temperature in the space below.

Write the definition of heat in the space below.

Section IB: Data table for the temperature of ice when it is heated

Time (sec)	Temperature (°C)
Initial	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	

Section IC: Questions relating to the experiment on heating ice

Why did the temperature of the ice and ice water remain constant throughout the experiment?

When water freezes there is no change in temperature, yet heat is liberated. Where does the heat come from, and why isn't there a change in temperature? Record your answer in the space below.

Section ID: Definitions

Place the definition of the melting point of ice and the freezing point of water in the space below.

Place the definition of fusion in the space below.

Place the definition of solidification in the space below.

Place the definition of heat of fusion in the space below.

Section IE: Questions relating to melting and solidification

Fill in the blanks with the proper word or term.

1. When most solids absorb sufficient heat, the temperature of the solid ______________.

2. The forces of attraction between molecules in the solid state are (stronger, weaker) ___________ than those in the liquid state.

3. When a solid melts, its _____________ energy is increased even though there is no change in temperature.

4. The temperature at which a substance melts is called its __________.

5. The process of melting is called __________.

6. The scientific term for the changing of a liquid to a solid is __________.

7. The number of calories needed to melt one gram of a substance without a change in temperature is called __________.

8. The temperature at which solidification occurs is known as the __________.

9. Pure substances generally have a __________ melting point.

10. The measure of the kinetic energy of molecules is called __________.

Check your answers before continuing.

SECTION II: HEAT OF FUSION OF ICE

Section IIA: Data table for the heat of fusion experiment

	Trial 1	Trial 2
1. Mass of the empty calorimeter	g	g
2. Mass of the calorimeter and warm water	g	g
3. Mass of the warm water (2 - 1)	g	g
4. Mass of the calorimeter and water (after ice is melted)	g	g
5. Mass of the melted ice (4 - 2)	g	g
6. Specific heat of the calorimeter	.22 cal/g/C°	.22 cal/g/C°
7. Initial temperature of the water and calorimeter	°C	°C
8. Final temperature of the water and calorimeter	°C	°C
9. Temperature change of the warm water and calorimeter (8 - 7)	°C	°C
10. Calories lost by the calorimeter (1 x 6 x 9)	cal	cal
11. Calories lost by the water (3 x 1 x 9)	cal	cal
12. Total calories lost (10 + 11)	cal	cal
13. Calories used to warm the ice water (5 x 8 x 1)	cal	cal
14. Calories used to melt ice (12 - 13)	cal	cal
15. Calories used to melt 1 g of ice (14 ÷ 5) (Calculated heat of fusion of ice)		
16. Accepted value for heat of fusion of ice	cal/g	cal/g
17. Error		
18. Percentage error $\left(\frac{\text{error (17)}}{\text{accepted value (16)}} \times 100\right)$	%	%

Section 11B: Calculations for the first trial of the heat of fusion of ice experiment

Calculate the mass of the warm water used in the experiment in the space below. Record this value in your data table on page 3.

Calculate the mass of the ice that was added in the space below. Record this value in your data table on page 3.

Calculate the temperature change of the water and calorimeter in the space below. Record this value in your data table on page 3.

Calculate the calories lost by the calorimeter in the space below. Record this value in your data table on page 3.

Calculate the calories lost by the warm water in the space below. Record this value in your data table on page 3.

Calculate the total calories lost. Record this value in your data table on page 3.

Calculate the calories used to warm the ice water formed by the melted ice in the space below. Record this value in your data table on page 3.

Calculate the calories used to melt the ice in the space below. Record this value in your data table on page 3.

Calculate the calories used to melt one gram of ice (heat of fusion of ice) in the space below. Record this value in your data table on page 3.

What is the accepted value for the heat of fusion of ice? ____________ calories/gram.

Calculate the error in your experiment in the space below. Record this value in your data table on page 3.

Calculate the percentage error in your experiment in the space below. Record this value in your data table on page 3.

Section IIC: Procedure for the second trial in the heat of fusion of ice experiment

1. Weigh the smaller can of your calorimeter on a triple beam balance. Record this weight in your data table on page 3 as the mass of the empty calorimeter.

2. Heat a beaker, three-fourths full of water, to a temperature of 40°C.

3. Fill the small can of the calorimeter about half full of warm water.

4. Find the mass of the calorimeter and warm water by weighing it on a triple beam balance. Record this mass in your data table on page 3 as the mass of the calorimeter and warm water.

5. Place the smaller can of the calorimeter inside the larger can. Stir the water in the calorimeter and read its temperature to the nearest 0.2°C. Record this temperature in your data table on page 3 as the initial temperature of the water and calorimeter.

6. Two ice cubes or an equivalent amount of ice lumps should be wiped with a paper towel to remove adhering water. Then put them in the calorimeter carefully so that there is no splashing.

7. Stir until all the ice is melted and read the thermometer to the nearest 0.2°C. Record the temperature in your data table on page 3 as the final temperature of the water and calorimeter.

8. Find the combined mass of the calorimeter and its contents. Record this mass in your data table on page 3 as the mass of the calorimeter and water after the ice is melted.

9. Do the calculations for the second trial of the experiment in the spaces provided in Section IID. Record all values in your data table on page 3 under Trial 2.

Section IID: Calculations for the second trial of the heat of fusion experiment

Calculate the mass of the warm water used in the space below. Record this value in your data table on page 3.

Calculate the mass of the ice that was added in the space below. Record this value in your data table on page 3.

Calculate the temperature change of the calorimeter and warm water in the space below. Record this value in your data table on page 3.

Calculate the calories lost by the calorimeter in the space below. Record this value in your data table on page 3.

Calculate the calories lost by the warm water in the space below. Record this value in your data table on page 3.

Calculate the total calories lost by the calorimeter and warm water in the space below. Record this value in your data table on page 3.

Calculate the calories used to warm the ice water formed by the melted ice in the space below. Record this value in your data table on page 3.

Calculate the calories used to melt the ice in the space below. Record this value in your data table on page 3.

Calculate the calories used to melt one gram of ice (heat of fusion of ice) in the space below. Record this value in your data table on page 3.

Calculate the error in your experiment in the space below. Record this value in your data table on page 3.

Calculate the percentage error in your experiment in the space below. Record this value in your data table on page 3.

Section IIE: Questions relating to the heat of fusion experiment

Answer the following questions that relate to the heat of fusion of ice experiment. Check your answers before continuing.

1. What is the heat of fusion of a solid?

2. List two possible sources of error in this experiment which have not been present in previous heat experiments.

   1.

   2.

Problems

Sample problem - How much heat is needed to change 50 grams of ice, at -20°C, to water at 0°C? Work this problem as it is worked on the slides and tape.

Problem 1 - How much heat is needed to change 35 grams of solid ice, at -10°C, to ice water at 0°C? Work this problem in the space below. Check your answer before working the next problem.

Problem 2 - How much heat is liberated when 40 grams of water at 0°C are changed to ice at -80°C? Work this problem in the space below. Check your answer before continuing.

Section IIF: Interpretation of the heat of fusion of ice graph

What does the horizontal line of the graph show? Record your answer in the space below.

Define the term, latent heat, in the space below.

Calculate the amount of heat needed to raise the temperature of one gram of ice at -20°C to 50°C. Do the calculation in the space below.

Calculate the value of the heat of fusion of ice in the British system of units; that is, in BTU's per pound. Show your work in the space below.

<u>Problems</u>

Problem 1 - How much heat is needed to convert 50 grams of ice at 0°C into water at 40°C? Work this problem in the space below. Check your answer to this problem before working the next problem.

Problem 2 - How much heat is needed to change 5.0 pounds of ice, at its freezing point, into water at 100°F? Work this problem in the space below. Check your answer to this problem before continuing.

SECTION III: VAPORIZATION AND CONDENSATION

Section IIIA: Defining vaporization and evaporation

Record the definition of vaporization in the space below.

Record the definition of evaporation in the space below.

Section IIIB: Data table for the evaporation experiment

	Thermometer #1	Thermometer #2	Thermometer #3
Initial temperature	°C	°C	°C
Final temperature	°C	°C	°C
Difference in temperature	°C	°C	°C

Section IIIC: Questions relating to the rate of vaporization

Why does evaporation cause cooling? Record your answer in the space below.

Why did the water freeze? Where did the heat go? Answer these questions in the space below. Check your answers before continuing.

Place the six ways in which the rate of vaporization of a liquid can be increased in the space below.

1.

2.

3.

4.

5.

6.

Section IIID: Questions relating to vaporization of a liquid

Answer these ten questions before continuing.

1. The process of converting a liquid to a vapor is called ____________.
2. If the above process occurs slowly without any visible disturbance in the liquid, it is called ______________.
3. Hot water evaporates (faster, slower) ____________ than cold water.
4. As the surface area of a liquid increases, its rate of evaporation (increases, decreases, stays the same) ________________.
5. Alcohol will evaporate (faster, slower) ________________ than ether at the same temperature.
6. As the air pressure increases, the rate of evaporation of a liquid (increases, decreases, stays the same) ________________.
7. Clothes will dry (faster, slower) ______________ on a windy day.
8. When a substance evaporates, it (loses, gains) ____________ heat energy.
9. The rate of vaporization of water (increases, decreases) ___________ when the amount of water vapor in the air decreases.
10. Different liquids evaporate at (the same, different) __________ rate(s).

Check your answers on the next slide.

SECTION IV: HEAT OF VAPORIZATION

Section IVA: Defining heat of vaporization

Record the definition for the heat of vaporization in the space below.

Section IVB: Data table for the heat of vaporization experiment

	Trial 1	Trial 2
1. Mass of the calorimeter	g	g
2. Specific heat of the calorimeter	0.22 cal/g/C°	0.22 cal/g/C°
3. Mass of the water and calorimeter	g	g
4. Mass of the water (3 - 1)	g	g
5. Initial temperature of the water and calorimeter	°C	°C
6. Temperature of the steam	°C	°C
7. Final temperature of the water, calorimeter and added steam	°C	°C
8. Mass of the water, calorimeter and added steam	g	g
9. Mass of the steam (8 - 3)	g	g
10. Temperature change of the water and calorimeter (7 - 5)	°C	°C
11. Temperature change of the water from the condensed steam (6 - 7)	°C	°C
12. Calories gained by the calorimeter (1 x 10 x 2)	cal	cal
13. Calories gained by the water (4 x 10 x 1 cal/g/C°)	cal	cal
14. Total calories gained (12 + 13)	cal	cal
15. Calories lost by the steam in condensing and cooling to final temperature (same as 14)	cal	cal
16. Calories lost after condensing (9 x 11 x 1 cal/g/C°	cal	cal
17. Calories lost by the steam in condensing (14 - 1 - 6)	cal	cal
18. Calories lost by 1 g of steam upon condensing (heat of vaporization) (17 ÷ 9)	cal	cal
19. Accepted value for the heat of vaporization	540 cal/g	540 cal/g
20. Error		
21. Percentage error $\left(\frac{\text{error}}{540\ \text{cal/g}} \times 100\right)$	%	%

Section IVC: Calculations for trial one of the heat of vaporization experiment

Calculate the mass of the cold water added to the calorimeter in the space below. Record this value in the data table on page 14.

Calculate the mass of the steam added in the space below. Record this value in the data table on page 14.

Calculate the temperature change of the water and calorimeter in the space below. Record this value in the data table on page 14.

Calculate the temperature change of the water that came from the condensed steam. Record this value in the data table on page 14.

Calculate the calories gained by the calorimeter in the space below. Record this value in the data table on page 14.

Calculate the calories gained by the cold water in the space below. Record this value in the data table on page 14.

Calculate the total calories gained by the cold water and calorimeter in the space below. Record this value in the data table on page 14.

Calculate the calories lost by the water, after condensing, as it cooled to the final temperature of the calorimeter and cold water. Record this value in the data table on page 14.

Calculate the calories lost by the steam, in condensing, in the space below. Record this value in your data table on page 14.

Calculate the calories lost by one gram of steam, upon condensing, in the space below. Record this value in your data table on page 14.

Calculate the error in your experiment. Record this value in your data table on page 14.

Calculate the percentage error in your experiment. Record this value in your data table on page 14.

Section IVD: Procedure for the second trial of the heat of vaporization experiment

1. Fill the steam generator about half full of water. Place the top on the generator and set the generator on the tripod.

2. Connect the glass tubing and water trap to the generator by means of small pieces of rubber tubing. Place the end of the water trap in the 250 ml beaker and light the burner.

3. Weigh the smaller can of the calorimeter on the triple-beam balance. Record its mass in the data table on page 14.

4. Fill the smaller can of the calorimeter two-thirds full of water. Weigh the water and calorimeter on the triple-beam balance. Record this mass in the data table on page 14.

5. Place the smaller can of the calorimeter inside the larger can, using the fiber ring to keep the cans apart. Stir the water with a thermometer and record the temperature, to the nearest 0.2°C, as the initial temperature of the calorimeter and water.

6. If steam has been passing out of the bottom opening of the water trap for three minutes, wipe off the bottom of the water trap with a towel. Now place only the bottom tube of the water jacket into the water in the calorimeter. Place the asbestos board between the generator and calorimeter.

7. Pass a steady current of steam into the water and stir continuously with your thermometer until the temperature of the water rises to about 45°C.

8. Remove the glass tube of the water trap from the calorimeter and place it in the 250 ml beaker. Stir the water in the calorimeter and read the temperature to the nearest 0.2°C. Record this value as the final temperature of the calorimeter and water.

9. Use a towel to remove the top of the steam generator. Be very careful because live steam can cause serious burns. Take the temperature of the boiling water to the nearest 0.2°C. Record this as the temperature of the steam.

10. Remove the inside can of the calorimeter. Be careful not to spill any water. Find the mass of the calorimeter, water and added steam. Record this value in your data table on page 14.

11. You are now ready to do the calculations for trial two of the experiment. Show your work and record all values in your data table on page 14.

Section IVE: Calculations for trial two of the heat of vaporization experiment

Calculate the mass of the cold water added. Record this value in the data table on page 14.

Calculate the mass of the steam added. Record this value in the data table on page 14.

Calculate the temperature change of the water and calorimeter. Record this value in the data table on page 14.

Calculate the temperature change of the water that came from the condensed steam. Record this value in the data table on page 14.

Calculate the calories gained by the calorimeter. Record this value in the data table on page 14.

Calculate the calories gained by the cold water. Record this value in the data table on page 14.

Calculate the calories gained by the cold water and calorimeter. Record this value in the data table on page 14.

Calculate the calories lost by the water, after condensing, as it cooled to the final temperature of the calorimeter and cold water. Record this value in the data table on page 14.

Calculate the calories lost by the steam in condensing. Record this value in the data table on page 14.

Calculate the calories lost by one gram of steam upon condensing. Record this value in the data table on page 14.

Calculate the error in your experiment. Record this value in the data table on page 14.

Calculate the percentage error in your experiment. Record this value in the data table on page 14.

Section IVF: Questions relating to the heat of vaporization experiment

Answer the following questions that relate to the heat of vaporization experiment. Check your answer to each question.

1. Why should the number of calories in Calculations 14 and 15 be equal? Check your answer to this question before answering question No. 2.

2. What are three possible sources of error in this experiment. Check your answer to this question before answering question No. 3.

   1.

   2.

   3.

3. The boiling temperature of a liquid varies with the atmospheric pressure. Does the heat of vaporization vary with the boiling temperature of a liquid? Explain your answer. Check your answer to this question before answering question No. 4.

4. Relate the two terms, heat of vaporization and heat of condensation. Check your answer to this question before continuing.

Problems

Sample problem - How much heat is needed to convert 50 grams of ice, at -5°C, to steam at 130°C? Work through this problem as the tape and slides solve it for you.

Problem 1 - How much heat is needed to raise the temperature of 20 grams of ice at 0°C to steam at 110°C? Check the answer to this problem before continuing.

Compute the heat of vaporization in British Thermal Units; that is, in BTU's per pound. Check your answer before continuing.

SECTION V: METHODS OF HEAT TRANSFER

Section VA: Conduction

Record your observations when the six inch copper wire was held in the burner flame for about five minutes.

How was the heat transmitted along the solid copper wire? Record your answer in the space below.

Record the definition of conduction in the space below.

What happened when the wire gauze was lowered onto the flame of your burner? Record your observation below.

Why didn't the flame pass through the copper gauze? Record your answer below.

What happened to the paper when the conductivity indicator was passed through the burner flame? Record your observations below.

Explain the above observations in the conductivity indicator experiment in the space below.

Record the order in which the paraffin melted in the six metal cavities of the conductometer apparatus.

Record your observations for the conductivity of water experiment in the space below.

Explain the observations you recorded in the conductivity of water experiment. Why didn't the ice melt in the bottom of the test tube?

Section VB: Questions relating to conduction

Answer these fill-in questions with the appropriate word or term. Check your answers on the next slide before continuing.

1. All metals are __________ conductors of heat.
2. Two metals that are very good conductors of heat are ______________ and ______________.
3. The transmission of heat by collisions between molecules is called ________________.
4. Wood, asbestos and rock wool are examples of __________ conductors of heat.
5. Liquids are __________ conductors of heat because their molecules are ______________.
6. Gases are ____________ conductors of heat because their molecules are ______________.
7. A good conductor is a ____________ insulator.
8. Conduction depends upon molecules ____________ and transferring their ____________ energy to slower moving molecules.
9. Substances that do not transmit heat easily are _____________ conductors.
10. Different metals conduct heat at (the same, different) ___________ rate(s).

Section VC: Convection

Record the definition of convection in the space below.

Record your observation of when the smoking touch paper was held above the right chimney of the convection box in the space below.

Explain your observation about the convection box experiment in the space below.

Place a labeled diagram of the hot air heating system in the space below.

Place a labeled drawing of land and sea breezes in the space below.

Record your observation concerning the heating of the beaker and potassium permanganate crystals.

Write your explanation as to why the convection current moved in the direction it did.

Make a labeled drawing of a hot water heating system in the space below. Note the slide.

Section VD: Questions pertaining to convection

Answer these ten fill-in questions pertaining to convection with the appropriate word or term. Check your answers before continuing.

1. The transfer of thermal energy by moving currents of molecules is called ______________.
2. Hot air is (heavier, lighter) ____________ than cold air.
3. Cold air is (more, less) ___________ dense than warm air.
4. Sea breezes take place (at night, during the day) _______________.
5. The heating effect of the sun upon the earth sets up huge _________ ______________.
6. Water, like air, is a good _____________ of heat.
7. Metals are (good, poor) ___________ convectors of heat.
8. The specific heat of land is (higher, lower) _____________ than that of water.

9. An island is surrounded by water. During the day, does the land heat up (faster, slower) ___________ than the water which surrounds the land?

10. The smoke from an open fire is carried upward by means of __________ currents.

Section VE: Radiation

Place the definition of radiation in the space below.

State the various ways in which the hot metal ball will lose heat.

Why is white clothing perferred to dark clothing in tropical countries, and why is a dark-colored suit more practical in winter in non-tropical regions? Record your answers in the space below.

Why don't we paint radiators black? Record your answer in the space below.

What happened when the burner flame was moved toward the radiometer?

Why did the speed of rotation increase and why did the vanes rotate in one direction?

This is the end of Unit VI. Review your notes and then ask your instructor for the examination covering this unit.

POSTTEST - UNIT V

Directions: In the blank at the left of each statement or term write the letter of the expression in the second column which is most closely related to it.

_____ 1. Thermal energy

_____ 2. Coefficient of volume expansion

_____ 3. Heat

_____ 4. Coefficient of linear expansion

_____ 5. calorie

_____ 6. BTU

_____ 7. Formula for the coefficient of linear expansion

_____ 8. Law of conservation of heat

_____ 9. Temperature

_____ 10. Units of temperature

_____ 11. To change calories to BTU's

_____ 12. Formula used to find the heat gained or lost by an object (heat equation)

_____ 13. To change BTU's to calories

_____ 14. Specific heat

a. Measures the average kinetic energy of molecules

b. The sum of the potential and kinetic energy of particles that can be given off as heat

c. An instrument that depends on unequal expansion of two metals

d. The change in length of a solid when its temperature is changed one degree centigrade

e. An instrument calibrated in degree units that measures temperature

f. Multiply by 252

g. Divide by 252

h. $\alpha \times l \times (t_2 - t_1)$

i. $\alpha \times \Delta l \times (t_2 - t_1)$

j. Amount of heat needed to change the temperature of one pound of water one Fahrenheit degree

k. Amount of heat needed to change the temperature of one gram of water one centigrade degree

l. Equals two times the coefficient of linear expansion

m. Equals three times the coefficient of linear expansion

n. Thermal energy being taken up or given up by a body

_____ 15.	Unit for specific heat	o.	Calorie
_____ 16.	Has the smallest thermal expansion	p.	The sum of the heat lost by hot objects equals the sum of the heat gained by cold objects
_____ 17.	Has the largest thermal expansion	q.	Degree
_____ 18.	Formula for finding percentage error	r.	$m \times s \times (t_2 - t_1)$
_____ 19.	Thermostat	s.	The amount of heat needed to raise the temperature of one gram of substance one degree centigrade
_____ 20.	Thermometer	t.	BTU/lb/C°
		u.	BTU/lb/F°
		v.	Solid
		w.	Liquid
		x.	Gas
		y.	$\frac{\text{accepted value}}{\text{error}} \times 100$
		z.	$\frac{\text{error}}{\text{accepted value}} \times 100$

<u>Directions</u>: Solve the following problems. Show your work in the space provided under each problem.

1. 800 grams of water is heated from a temperature of 20°C to a temperature of 80°C. How much heat was absorbed by the water?

2. Compute the final temperature of 50 pounds of water, initially at 40°F, if 1,000 BTU's of heat are added.

3. A beaker contains 200 grams of water at a temperature of 25°C. How many grams of hot water, at a temperature of 85°C, must be added to raise the temperature of the cold water to 45°C?

4. A student did an experiment in the determination of the specific heat of a solid. His data table is below. You are to calculate the specific heat of this solid.

mass of the calorimeter	110 g
specific heat of the calorimeter	0.09 cal/g/C°
mass of the water	405 g
mass of the solid	201.9 g
initial temperature of the water and calorimeter	20°C
initial temperature of the solid	100°C
final temperature of the water, calorimeter and solid	23.5°C

5. An iron rod is 60 cm long at 0°C. How much will it expand when heated to 80°C? What will be its length at 80°C. The coefficient of iron is 0.000011 cm/C°.

POSTTEST - UNIT VI

Directions: Write the definition for the following words or terms. The answers are to be placed in the space below each word or term.

1. Heat of fusion

2. Heat of vaporization

3. Fusion

4. Solidification

5. Latent heat

6. Vaporization

7. Water cycle

8. Conduction

9. Convection

10. Radiation

Directions: Indicate which method of transfer of heat--conduction, convection, or radiation--is chiefly concerned with each of the following. Place your answer in the blank at the left of each statement.

1. ______________ - Snow melts more rapidly if covered with something dark.

2. ______________ - In summer the basement is usually the coolest place in the house.

3. ______________ - Hot air furnaces are placed in the basement.

4. ______________ - Your finger is burned if you touch a hot stove.

5. ______________ - A concave reflector is used with an electric heater.

6. ______________ - Light-colored clothing is cooler in the summer.

7. ______________ - The sides of a thermos bottle are silvered.

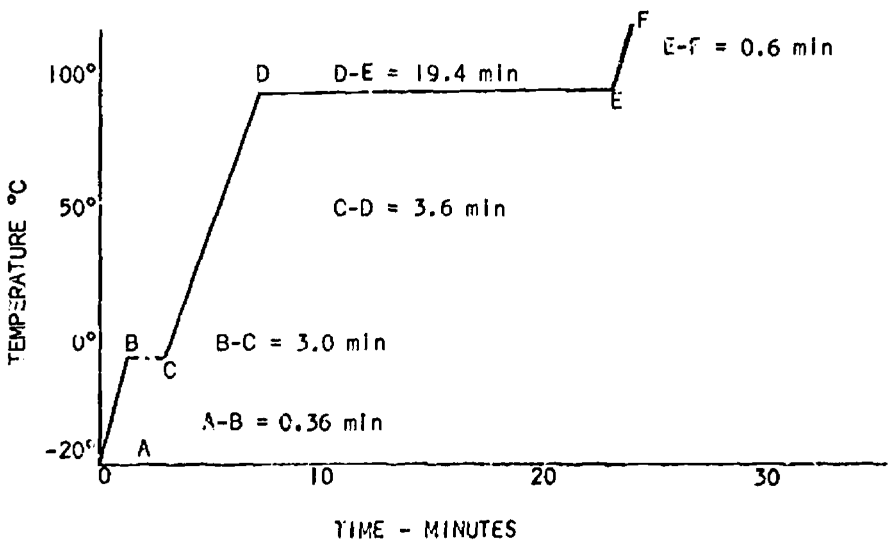
8. ______________ - A silver spoon is placed in a glass jar to keep it from cracking when a hot substance is poured into the jar.

9. ______________ - The cooling unit of a refrigerator is in the top.

10. ______________ - Soldering irons have tips of cooper instead of iron.

The following questions pertain to the graph below obtained by plotting data for the heating curve obtained in the following experiment:

> A pure solid substance was heated over a temperature range by a constant source of heat which supplied 500 calories per minute to a 18 gram sample of the substance. The temperature of the sample was noted every half minute.



1. The portion of the graph between B and C represents the time the substance is: (1) being warmed as a solid; (2) being warmed as a liquid; (3) being warmed as a gas; (4) changing from solid to liquid at its melting temperature; (5) changing from liquid to gas at its boiling temperature.

   _______ answer

2. The portion of the graph between C and D represents the time the substance is: (1) being warmed as a solid; (2) being warmed as a liquid; (3) being warmed as a gas; (4) changing from solid to liquid at its melting temperature; (5) changing from liquid to gas at its melting temperature.

   _______ answer

3. How much heat is required to melt the substance?

   _______ answer

4. What portion of the graph represents the warming of the solid substance: (1) A-B; (2) B-C; (3) C-D; (4) D-E; (5) E-F.

_______ answer

5. In which portion of the curve do the molecules have the highest energy of motion--kinetic energy? In the region from: (1) A-B; (2) B-C; (3) C-D; (4) D-E; (5) E-F.

_______ answer

6. The portion of the graph between D and E represents the time the substance is: (1) being warmed as a solid; (2) being warmed as a liquid; (3) being warmed as a gas; (4) changing from solid to liquid at its melting temperature; (5) changing from liquid to gas at its boiling temperature.

_______ answer

7. How much heat is required to vaporize the 18 gram sample?

_______ answer

8. In which portion of the curve do the molecules have the lowest energy of motion--kinetic energy? In the region from: (1) A-3; (2) B-C; (3) C-D; (4) D-E; (5) E-F.

_______ answer

9. What is the numerical value for the heat of fusion of the substance? Show your work in the space below. Place your answer in the blank.

_______ answer

10. What is the numerical value for the heat of vaporization of the substance? Show your work in the space below. Place your answer in the blank.

_______ answer

Solve the following problems. Show all work in the space provided for each problem. Use the back of this page for your work, if necessary.

1. How much heat is needed to completely vaporize 20 pounds of water at 80 degrees Fahrenheit?

2. Calculate the energy in calories released when 10.0 grams of water vapor at 120°C are converted into ice at -20°C.